International Journal of Electrical, Computing Engineering and Communication (IJECC)
Vol. 1, Issue. 3, June – 2015 *ISSN (Online): 2394-8310*

A Descreening model based on anisotropic diffusion tuned Edge-preserving and Redundancy Filters

[1]K.Polaraju, [2]K.N.V.Suresh Varma
[1]ME student, [2]Assistant professor, [1,2]Department of ECE,
S.R.K.R Engineering College, Bhimavaram, Andhrapradesh, INDIA,
kesanapallipolaraju@gmail.com, Knvsureshvarma@yahoo.co.in

***Abstract*— Halftoning is a technique used in printers to print continuous tone images. All the images from newspapers, magazines, and journals are printed using halftoning technique. If a halftoned image is scanned, scanned image quality is degraded by random noise. If the scanned image is reprinted moiré pattern appear on printed image. This degrades the image quality so inverse halftoning or descreening should be performed to recover continuous tone image from scanned halftone image. Inspired by anisotropic diffusion and bilateral filter we propose a descreening method to produce continuous tone image with sharper edges. In this model redundancy based filter like bm3d filter is used to suppress random noise while modified anisotropic diffusion and bilateral filter are used to remove halftones.**

***Keywords*— Halftoning, moiré effect, descreening, anisotropic diffusion, redundancy based denoising, bilateral filter.**

I. INTRODUCTION

The majority of existing printers are unable to produce continuous tone images because the tones or color inks used in printing are limited. Halftoning process has been practiced for many years in printing process to print continuous tone images on the plane of paper. Halftoning [1], [2] is a technique used to convert continuous tone images to discrete tone images. In halftoning process dots of various sizes arranged at various distances to makes visual illusion of an original continuous tone image. Halftoning can be considered as quantization process that decreases the bit depth of the image while maintaining its visual appearance. However human eye can not perceive the discreteness of halftone image due to its low pass filtering nature.

Halftone images are of two types, gray scale halftone images and color halftone images. Gray scale halftone images are usually generated by using single color ink dot patterns of varying sizes are placed at various distances where as color halftone images generated by using four color ink dot patterns that are overlapped at different angles. Cyan, magenta, yellow and black are the colors used in color halftoning. Visual illusion of all the colors is produced by varying the sizes and relative positions of dots and overlapping angles among four screens.

Conventional halftoning methods are mainly classified into two types. They are amplitude modulation (AM) halftoning and frequency modulation (FM) halftoning. In amplitude modulation (AM), halftoning is performed by varying the size of the halftone dots where as in frequency modulation (FM), halftoning is performed by changing spacing between the dots or their relative density. The popular method used for AM halftoning is clustered dot screening [3] where as dispersed dot screening [4], [5], [6] and error diffusion [7] are widely used FM halftoning techniques.

Clustered dot screening [3] is a widely used halftoning method which produces gray scale halftone images by using regular grid pattern of dots of different sizes. Currently, clustered dot halftoning is widely used in the printing of news papers, magazines and books. If a clustered dot halftone image is required to scan for some purpose, the quality of the scanned copy degraded to an intolerable level due to the introduction of artifacts like moiré artifacts. The image quality becomes too poor and it is easily perceived by human eye. The word Moiré is used to illustrate interference due the overlapping of similar patterns at an acute angle. When a clustered dot halftone image is scanned, due to interference between the tilted half tone grid and vertical scanning grid causes moiré artifacts. Moiré patterns also generated due to frequency difference between two screens. Descreening should be applied to scanned halftone images to improve its quality. Descreening or inverse halftoning is the process of retrieving the continuous tone image from halftone image.

In this paper, we propose a descreening model which makes use redundancy filtering, modified non iterative anisotropic filtering and edge preserving filter for descreening. Redundancy based filter like bm3d filter is used to remove moiré artifacts while non iterative anisotropic diffusion and edge preserving filter like bilateral filter remove halftones and sharpen the edges.

Proposed descreening model is slightly similar to redundancy and adaptive filtering based descreening which is proposed by Bin Sun and Shutao Li. In both techniques, redundancy based filter is used to suppress scanning noise. The main difference between these two techniques is that in Bin Sun’s model steerable filters are used to tune bilateral kernel coefficients while in proposed model anisotropic diffusion is used to tune the bilateral filter coefficients.

The rest of the paper organized as follows. In section II, we explain in detail about proposed descreening model. In section III, we describe about experimental results. Finally in section IV, we conclude the paper.

II. AN OVERVIEW OF PROPOSED DESCREENING MODEL

In the proposed descreening model, scanned copy of clustered dot halftone image is subjected for descreening. The proposed descreening model consists of three sequential steps.

A. Applying redundancy based filter
B. Applying modified anisotropic filter
C. Applying edge preserving filter

The following block diagram shows an over view of our proposed model.

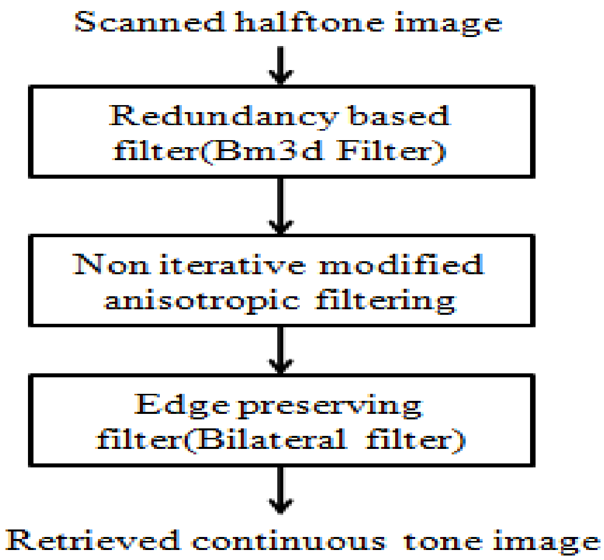

Fig.1 Overview of proposed descreening model

A. Redundancy based filter:

In this model, redundancy based filter is used to remove random noise, moiré artifacts and printing distortions. Redundancy based filter is very effective when the redundancy in image content is more. In this model, redundancy based filter is chosen because of repeated pattern of halftones. In this model, block matching three dimensional collaborative (bm3d) filter [8] is chosen for redundancy based filtering. As name suggests, the filtering process is based on block matching and collaborative filter of image blocks. The operation of bm3d filter is divided into two steps.

1. To obtain basic estimate of denoised image:
   a. Divide the noisy input image into overlapping blocks or patches.
   b. Perform grouping by collecting similar blocks and forming them into 3d array form.
   c. Apply 3d transform to a group, perform hard threshold or shrinkage to remove noise and apply inverse 3d transform to the group
   d. Apply aggregation to get clear blocks or patches.
2. To obtain final estimate of denoised image:
   a. Divide the basic estimate of denoised image into overlapped blocks or patches
   b. Perform grouping by collecting similar blocks and forming them into 3d array form.
   c. Apply 3d transform to a group, perform wiener filtering to remove noise and apply inverse 3d transform to the group
   d. Apply aggregation to get clear blocks or patches.

In bm3d filter, grouping of similar blocks is obtained by using k-means clustering or fuzzy clustering. In hard thresholding, noise coefficients can be directly removed by setting some threshold value. Aggregation is the process of the weighted average of all the blocks to get clear blocks.

The 3d transform is advantageous because it gives sparse representation of image blocks in a group. Sparse representation makes shrinkage effectively to remove noise while preserving image details. This approach of using image redundant content to get denoised image is known as collaborative filtering.Bm3d filter effectively removes additive white Gaussian noise (AWGN) by which the real time images corrupted.

In this model, it is unknown the noise density of noisy scanned images. If low noise density is taken, noise couldn't be removed effectively where as if high noise density is taken image details will be filtered out so noise density should be taken appropriately.

B. Non iterative modified anisotropic diffusion:

In the proposed descreening model, a non iterative anisotropic diffusion is used, which is proposed by Hasib Siddiqui and Mireille Boutin [9].They proposed the non iterative anisotropic diffusion inspired by anisotropic diffusion which is proposed by Perona and Malik [10]. Anisotropic diffusion is applied to smooth the noise in degraded images while maintaining the edges. According to Perona and Malik equation of nonlinear anisotropic diffusion is

$$\begin{aligned} u_{i,j}^{n+1} = u_{i,j}^{n} + \lambda \ \Big[& g\left(\left|u_{i-1,j}^{n} - u_{i,j}^{n}\right|\right).\left(u_{i-1,j}^{n} - u_{i,j}^{n}\right) \\ & + g\left(\left|u_{i+1,j}^{n} - u_{i,j}^{n}\right|\right).\left(u_{i+1,j}^{n} - u_{i,j}^{n}\right) \\ & + g\left(\left|u_{i,j-1}^{n} - u_{i,j}^{n}\right|\right).\left(u_{i,j-1}^{n} - u_{i,j}^{n}\right) \\ & + g\left(\left|u_{i,j+1}^{n} - u_{i,j}^{n}\right|\right).\left(u_{i,j+1}^{n} - u_{i,j}^{n}\right)\Big] \quad (1) \end{aligned}$$

Where $u_{i,j}$ denotes the intensity of target pixel $u(i,j)$ and $u_{i-1,j}, u_{i+1,j}, u_{i,j+1}, u_{i,j-1}$ represent the intensities of four neighbors of target pixel. λ is a normalizing constant to control the rate of diffusion whose value can be taken in between 0 and 0.25. $g(x)$ is an edge stopping function which a non negative decreasing function which is selected empirically and n represent state of time. In anisotropic diffusion noise smoothing is performed iteratively using the image details of previous state of time in present state of time. The number of iterations that are used for diffusion depends on noise density of degraded images. For some images like noisy scanned images noise density is unknown so number of iterations should be required for effective diffusion is also unknown.

Hasib Siddiqui and Mireille Boutin propose a non-iterative filter for effective anisotropic diffusion where noise density is unknown. The filtering operation is non linear in nature. According to Hasib Siddiqui and Mireille Boutin, the anisotropic diffusion equation (1) is modified as follows

$$v_{i,j} = u_{i,j} + \lambda \quad [g\left(y_{i-1,j}.f(y_{i,j})\right).(z_{i-1,j} - z_{i,j}) + g\left(y_{i+1,j}.f(y_{i,j})\right).(z_{i+1,j} - z_{i,j}) + g\left(y_{i,j-1}.f(y_{i,j})\right).(z_{i,j-1} - z_{i,j}) + g\left(y_{i,j+1}.f(y_{i,j})\right).(z_{i,j+1} - z_{i,j}) \quad (2)$$

Where $z_{i-1,j}$, $z_{i+1,j}$, $z_{i,j-1}$, $z_{i,j+1}$ are the local pixel averages calculated at $u(i-1,j), u(i+1,j), u(i,j-1), u(i,j+1)$ respectively. $y_{i,j}$, $y_{i-1,j}$, $y_{i+1,j}$, $y_{i,j-1}$, $y_{i,j+1}$ are the norms of image gradient vectors calculated at pixels $u(i,j)$,$u(i-1,j)$,$u(i,j-1)$,$u(i,j+1)$ respectively. The functions g(x) and f(x) are selected empirically which are non linear functions.

In smooth image regions the function $g(x)$ value will become unity so equation (2) is modified to

$$v_{i,j} = \lambda\left[z_{i-1,j} + z_{i+1,j} + z_{i,j-1} + z_{i,j+1}\right] \quad (3)$$

$$= \frac{\sum_{m1,m2} h_{m1,m2} u_{i+m1,j+m2}}{\sum_{m1,m2} h_{m1,m2}} \quad (4)$$

Where

$$h_m = \frac{1}{256}\begin{bmatrix} 1 & 2 & 3 & 4 & 3 & 2 & 1 \\ 2 & 4 & 6 & 8 & 6 & 4 & 2 \\ 3 & 6 & 9 & 12 & 9 & 6 & 3 \\ 4 & 8 & 12 & 16 & 12 & 8 & 4 \\ 3 & 6 & 9 & 12 & 9 & 6 & 3 \\ 2 & 4 & 6 & 8 & 6 & 4 & 2 \\ 1 & 2 & 3 & 4 & 3 & 2 & 1 \end{bmatrix}$$

h_m is a low pass smoothing filter which can effectively smoothen the halftones. $m = (m1, m2)$ represent the image coordinates.

C. Edge preserving filter:

It is important to preserve edges in retrieved continuous tone image. To preserve sharp edges, edge preserving filter is applied. In this descreening model bilateral filter is chosen for edge preserving filtering [11].

The filtering operation of bilateral filter is almost similar to Gaussian convolution. In both filters filtering operation is defined as the weighted average of neighbors within the window. Only difference is that, in bilateral filter the differences between the neighbors with respect to target pixel are considered additionally. In this way edges are preserved while noise is smoothened. The equation of bilateral filtering operation [12] at target pixel $v(m_1, m_2)$ is given by

$$c(m1, m2) = z^{-1} \sum_{x=-r}^{r} \sum_{y=-r}^{r} h_s(x, y) h_b(x, y)\, v(m1 + x, m2 + y) \quad (5)$$

Where

$$h_s(x, y) = \mathrm{e}^{-\frac{x^2+y^2}{2\sigma_s^2}}$$

$$h_b(x, y) = e^{-\frac{(v(m1+x\,,m2+y)-v(m1,m2))^2}{2\sigma_b^2}}$$

$$z = \sum_{x=-r}^{r} \sum_{y=-r}^{r} h_s(x, y) h_b(x, y)$$

$r =$ Kernel radius

The bilateral kernel is formed by element wise multiplication of Gaussian convolution kernel with a kernel of same size have weights that are taken based on image pixel intensity differences in the local window.

If the difference between the neighbor and the target pixel is small which means there is no edge at target pixel then bilateral kernel tends to gaussian convolution kernel. If the difference between the neighbor and target pixel is a large value which mean there is an edge then bilateral filter is applied to preserve edge.

The parameters σ_s, σ_b specify the amount of filtering needed to apply on the image. The parameters selected empirically. The values should be selected carefully for effective edge preserving filtering.

III. EXPERIMENTAL RESULTS

The performance of proposed descreening model was tested on scanned clustered dot halftone images from news papers. The scanned copies scanned at 300 dpi on EPSON 210 scanner .The program code of proposed model is implemented in MATLAB and executed on personal computer with dual core processor and 4GB RAM. The execution time of entire code is 1.45 minutes. The following table shows parameter values chosen for descreening.

Table.1 Parameter values of proposed model

Filter	parameter	value
Redundancy filter	Estimated noise level	15
Edge-preserving filter	σ_s	3.5
	σ_b	0.1

The following figures show the scanned images and their corresponding retrieved continuous tone images.

1) Salman.png

Fig.2 Scanned halftone image of salman

Fig.3 Retrieved continuous tone image of salman

2) Dogs.png

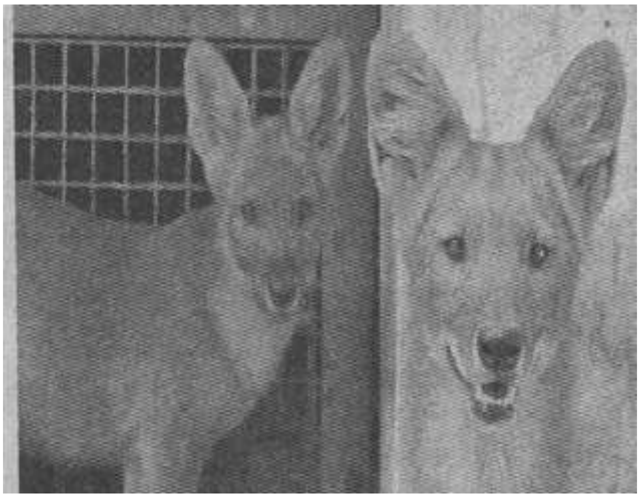

Fig.4 Scanned halftone image of dogs

Fig.5 Retrieved continuous tone image of dogs

3) Leo.png

Fig.6 Scanned halftone image of Leo

Fig.7 Retrieved continuous tone image of Leo

4) Car.png

Fig.8 Scanned halftone image of car

Fig.9 Retrieved continuous tone image of car

IV. CONCLUSION

Good quality images are always preferred in image processing. In this paper, we propose a descreening model for degraded scanned images. This model retrieves the continuous tone images with sharper edges and provides better computation efficiency. This descreening model can be applied only to gray scale halftone images. Our future work includes the experiments on descreening of color halftone images.

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